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IRON-TITANIUM OXIDE MINERALS IN THE HIGH-IRON CONCENTRATION TYPE OF BASALTS IN THE DECCAN TRAPS

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ABSTRACT

The Deccan Trap basalts of Bhopal are high-iron concentration types of tholeiites. Various forms and mode of occurrence is described. The growth of the crystals through stages are discussed. A gradual decrease in the degree of oxidation from the bottom to top flows is noticed. The iron enrichment remaining constant the oxidation ratio show a gradual rise. Studies in reflected light under the ore microscope show the presence of the following types of the iron ores; magnetite, ilmenite, titanomagnetite and scarcely hematite. An account of the paragenesis of these opaques is presented.

INTRODUCTION

The earliest account of the iron-ores of the Deccan Traps was given by FERMOR [1925] who suspected the presence of both magnetite and ilmenite in these rocks. Normative constituents can not explain the actual mineral composition of the rocks. However, the square opaques were taken by him as magnetite while the bars and streaks as ilmenite. Many years later DE [1964] studied the opaques under the reflected light and found that the most abundant and common opaque mineral is titano-

TABLE 1

Some characteristic data of the basalts investigated

Nos.	Sequence of the flows	FeO	Fe_2O_3	TiO_2	H_2O	Oxidation ratio	Degree of oxidation
1.	6th Flow (Et 3)	12.19	3.06	2.11	+2.24	—	0.25
2.	5th Flow (B6)	10.75	4.48	2.90	+1.66 −0.18	27.27	0.42
3.	4th Flow (H5)	10.35	5.22	3.10	+2.64 −0.24	31.22	0.50
4.	3rd Flow (H_{13})	10.18	5.17	3.10	+2.32 −0.36	31.36	0.51
5.	2nd Flow (B_{42})	9.17	6.30	2.90	+3.04 −0.38	38.33	0.68
6.	2nd Flow (B_{15})	9.14	6.47	3.11	—	49.11	0.71
7.	1st Flow (B_1)	8.80	6.27	2.20	+1.26 −0.14	39.08	0.71

Analyst: B. P. GUPTA

magnetite. DE subsequently [1974a] demonstrated the occurrence of silicate-liquid immiscibility in the mesostasis of the Deccan Trap basalts. He further documented [1974b] the co-existence of three mutually immiscible liquid phase in the residual magma of the Deccan Traps.

The Deccan Trap basalts are in general moderate iron-concentration type the $FeO + Fe_2O_3$ content being less than 15 per cent. But the various flows studied from near Bhopal range between 17.12 and 15.23 [CHATTERJEE, 1973] indicating their high iron concentration (Table 1). In the present account the mineralogy of the iron-titanium minerals of these basalts is discussed.

MODE OF OCCURRENCE IN THIN SECTION

Various modes of occurrence and forms are recorded. They are mainly associated with glass. The streaks are found to cut across the plagioclase and pyroxene phenocrysts. Diversity of forms of these opaques often occur in the same section. They are mostly found to occur as follows:

1. Squarish to equidimensional
2. Irregular granules
3. Streaks
4. Tiny needles.

It appears that the squarish, idiomorphic and occasionally equidimensional grains probably did not form by simple enlargement of minute crystals, but many small grains gradually clustered. The growth of the minute crystals in the initial stage might have started at the end of the bars. Such bars which initially had cross arms would change to an equidimensional large crystal. In some of the large grains the sharp octahedral corners, still persisting, confirm this. TALUKDAR [1963] predicted the formation of the long narrow bands by joining of the squarish or rhomshaped grains. The streaks resulted due to the joining crystallites along a definite direction. The dendrites and skeletal crystals are the results of incomplete growth.

DESCRIPTION OF THE POLISHED SECTIONS

The opaques on the whole do not show much variation from flow to flow. The various minerals identified under the ore-microscope include the following: magnetite, ilmenite, titanomagnetite, hematite, chalcopyrite, etc. A brief description of the above stated occurrences are summarized below.

Magnetite: In a coarse grained non porphyritic flow nearly equidimensional grains of partly martitized magnetite, occasionally containing specks of ilmenite as inclusions are recorded. In a fine grained porphyritic flow the grains are equidimensional euhedral containing silicate inclusions. Some xenomorphic forms interstitial to silicates are also noticed. Prismatic rods are rarely recorded. In this flow the martitization of magnetite is completely absent. In another flow (fine-grained porphyritic) magnetite-ulvospinel intergrowth is very distinct. Here the reflectivity is low, anisotropism weak and the colour is a little more brownish than magnetite. Replacement of grains of magnetite by minor amount of maghemite is recorded in a fine-grained non-porphyritic flow.

Ilmenite: It occurs as coarse-prism and rods or as specks of inclusions. In fine-grained porphyritic flow this is the most dominating opaque mineral. The colour varies from brownish grey to pale brown, the pleochroism and anisotropism being very strong. Twinning is noticed in the ilmenite of the present flow. Exsolved ilmenite with titan-magnetite is also recorded in certain sections.

Titanomagnetite: Magnetite with dissolved titanium. In some cases exsolved ulvospinel is also visible. Weakly anisotropic. Colour more brownish than that usual with magnetite. Reflectivity slightly low. Exsolved ilmenite with ülvospinel is also found. DE [1964] has deduced that the oxygen fugacity in the Deccan Trap basalts at 1100°C was about 10^{-10} atm when the titanomagnetite crystallized.

Hematite: Numerous small specks of hematite within the pyroxene grains are recorded in a coarse-grained flow. Hematite follows the cleavage planes of the host. The mode of occurrence suggests that this hematite is not primary in origin, but the iron probably was liberated during the break down of the pyroxenes. However, when compared with the thin sections, it is found that the pyroxenes are remarkably fresh, though opaques do occur along the cleavage planes. Since thin section study do not confirm their secondary origin, they must have formed when O_2 in the gases reacted with the iron-bearing minerals under conditions of lower temperature and inequilibrium. This happens when bubbles form in the lavas, since then the vapour does not remain in equilibrium with the crystals and melt [CORNWALL, 1951a].

Chalcopyrite: Besides the iron-titanium oxide minerals this mineral rarely occurs as tiny grains or globules with typical brass-yellow colour. They are frequently replaced by bornite (vein replacement and rim replacement).

CHEMICAL CONSIDERATIONS

Degree of oxidation [BUDDINGTON *et al.* 1963] is based on the ratio of Fe_2O_3 to FeO. Reference to Table 1 will confirm a gradual decrease in the degree of oxidation towards the younger flows. WILKINSON [1957] made the concentration of pressure of water in the melt directly responsible for the state of oxidation. High H_2O, according to him, would result in high Fe_2O_3/FeO ratio. The Bhopal basalts do not bear testimony to this. Since specimen H_{13} shows 2.68 per cent H_2O where the ferric to ferrous ratio is 0,50; as against this the ratio is 0.71 (B_1) for a rock where the water content 1.40. It seems that other major features, such as partial oxygen pressure [OSBORNE, 1959], and the bulk composition might have been responsible for the variation in the degree of oxidation [BUDDINGTON *et al.* 1963].

Gradual rise in the iron-enrichment with the rise of oxidation ratio [DE, 1964, p. 130], is the general trend of Deccan Traps. But the Bhopal basalts on the contrary show a rise in oxidation ratio, the iron-enrichment — remaining constant. Probably a variation in the oxidation ratio takes place in various suites.

ORDER OF CRYSTALLIZATION

In such sections where crystals of opaques are recorded the following features are seen: —

i) Large crudely idiomorphic grains are occurring either interlocking with pyroxenes or are found to have inclusions of pyroxenes in them. Occasionally pyroxene plates are also seen to enclose the grains of opaques.

ii) The plagioclase laths are frequently poikilitically enclosed by the opaques; or are projecting into the opaques. The skeletal form or the rod like forms of the opaques cut across the earlier formed (more calcic) plagioclase laths.

iii) The opaques are not seen as crystals in high glassy rocks. Under the high power objective numerous black dots are seen along with glass, making the colour extremely dark. A concentration of iron-ores in the residual liquid is the possibility.

iv) A comparison of the percentage of iron-ores with the sum of normative magnetite and ilmenite always indicate a greater percentage of normative ores. This is possible only due to the enrichment of iron at a late stage and thus crystals were not encountered in modal counting. This is quite apparent from the following observations.

Section Nos.	B_1	B_6	B_{42}	H_5	H_{13}
Modal percentage	8.5	7.9	8.1	No crystal	9.4
Norm percentage	13.31	11.97	14.52	13.31	13.59

PARAGENESIS

Depending on degree of crystallization two stages were identified by DE [1974d], which is (*A*) crystallization of plagioclase and augite and (*B*) where crystallization of iron ores (titanomagnetite and ilmenite) comes in a dark brown coloured glass. Naturally a considerable iron-enrichment should take place in the residual liquid before stage *B*. In the present area also titanomagnetite and ilmenite are recorded in the dense black glass of the thin sections. It is reasonable to postulate that they are later than the 'intra-telluric'-crystals. Large idiomorphic and elongated bars of opaques (magnetite) exhibiting inter-locking relationship with pyroxene indicate that they crystallized partly simultaneously [CHATTERJEE, 1973]. Titanomagnetite skeletals in the interstitial space or in the opaque glassy groundmass indicate their later generation. Ilmenite does not occur in the skeletal forms either in the glassy base or in the interstitial glass. The intergrowth relationships, however, suggest that it started crystallizing simultaneously with titanomagnetite and ilmenite must had a shorted period of crystallization. The present writer [1971] has earlier referred to the enrichment of silica and alkali in the last fraction of the cooling magma (glass). More recently DE [1974] predicted that under certain conditions of moderately high oxygen fugacity the residual basalt magma may pass over the immiscibility field at temperature higher than the upper, consolute temperature, crystallizing pyroxene and iron ore (+plagioclase in a natural basalt) giving rise to the above stated conditions.

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